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UNITED STATES BUREAU OF MINES
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BUREAU OF MINES APPARATUS FOR DEMONSTRATING ELECTRICAL IGNITION OF MINE GAS

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BY

E. J. GLEIM

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DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

BUREAU OF MINES APPARATUS FOR DEMONSTRATING ELECTRICAL IGNITION OF MINE GAS[1]

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By E. J. Gleim[2]

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Many people consider the mining of coal to be an extremely hazardous occupation; but it should be remembered that most large industries have to meet special conditions, which, if not dealt with properly, might become hazards to life and property. Mining men may not always be fully aware that some practices and certain equipment that is incorrectly designed or maintained can lead to dangerous conditions. In endeavoring to help the coal-mining industry to prevent accidents and disasters, the Bureau of Mines has engaged in a program of education on conditions and practices that must be avoided. An effective way to teach safety is by visual demonstration. For example, it is generally known that certain kinds of electrical flashes have ignited explosive atmospheres in mines, but actually to see and hear explosions caused by electrical sparks of different size and character under laboratory control is likely to teach a much more emphatic and lasting lesson than would be learned by merely reading about them. The interest manifested by those who witness the demonstrations seems to prove that this is true.

The purpose of the demonstrations is not to discourage the use of electricity in mines, but rather to indicate what types of equipment (including some generally regarded as harmless) can ignite gas and what safeguards have been developed to prevent such ignitions. It is hoped that this information will improve the ability of mining men to cope with underground hazards.

Two types of demonstration apparatus have been constructed to show how mine explosions can be started by large or small sparks from equipment in common, everyday use. One type is portable and so equipped that it can be readily set up in districts easily reached by mining men. The

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other type is permanently installed in the electrical laboratory of the Bureau's Pittsburgh Experiment Station, where any interested visitor may see a demonstration. Included in the latter apparatus is a row of 10 chambers made with glass cylinders, each 7 inches in diameter and 12 inches in height. The glass walls are 1/4 inch thick. Each cylinder is held with its axis vertical between two aluminum plates, which are grooved to take the cylinder ends and have rubber gaskets to form gas-tight joints. The top plates have a 5-1/2-inch-diameter circular opening which can be sealed tightly with waxed paper held in place by special rubber cement. When an explosion occurs in the chamber the waxed paper bursts and releases the expanding gases before enough pressure can develop to strain the glass wall.

Explosive mixtures are made in these chambers by introducing Pittsburgh natural gas into the contained air. Pittsburgh natural gas contains approximately 85 percent methane, the chief combustible gas found in coal mines, and is therefore a satisfactory laboratory substitute for pure methane. The required amount of gas is obtained by timing the flow of gas through a small orifice under the base of each chamber, the number of seconds flow having been determined previously by calibration. As the gas flows into the chambers the difference in pressure between the inside and the outside is allowed to equalize through 1/8-inch-diameter hole that is sealed shut by a corner of the waxed paper after the gas has been shut off. The mixture is therefore under atmospheric pressure and contains 8 to 10 percent of gas by volume. Figure 1 is a sectional view of one of these demonstration chambers.

Under each chamber is a brief printed statement of the hazard represented therein, together with a photograph and short description of equipment that can be used as a protection against that hazard.

In the first chamber, beginning at the left end of the row, are two pieces of cable mounted in such a way that one of them can be made to touch the other momentarily and thus strike an arc when potential is applied. This represents a feeder or other power cable that may become short-circuited in consequence of being struck by falling material or by derailed cars. For this demonstration, a potential of 110 volts direct current is applied with a resistor in the circuit to keep the current down to 10 amperes. This readily ignites the explosive mixture, and the waxed paper is ruptured.

In the next chamber is a short piece of trolley wire and a trolley wheel arranged to make and break contact with it so as to draw an arc. The trolley locomotive as ordinarily operated in coal mines may have a stream of sparks trailing behind it as the wheel travels along the wire. If an explosive mixture is present, it is almost certain to be ignited by these sparks. The demonstration is made with a current of 10 amperes and 110 volts direct current, which easily explodes the mixture in the chamber.

Another source of sparking is to be found at joints in rails that are part of the return circuit for the trolley system. Here the copper bonds

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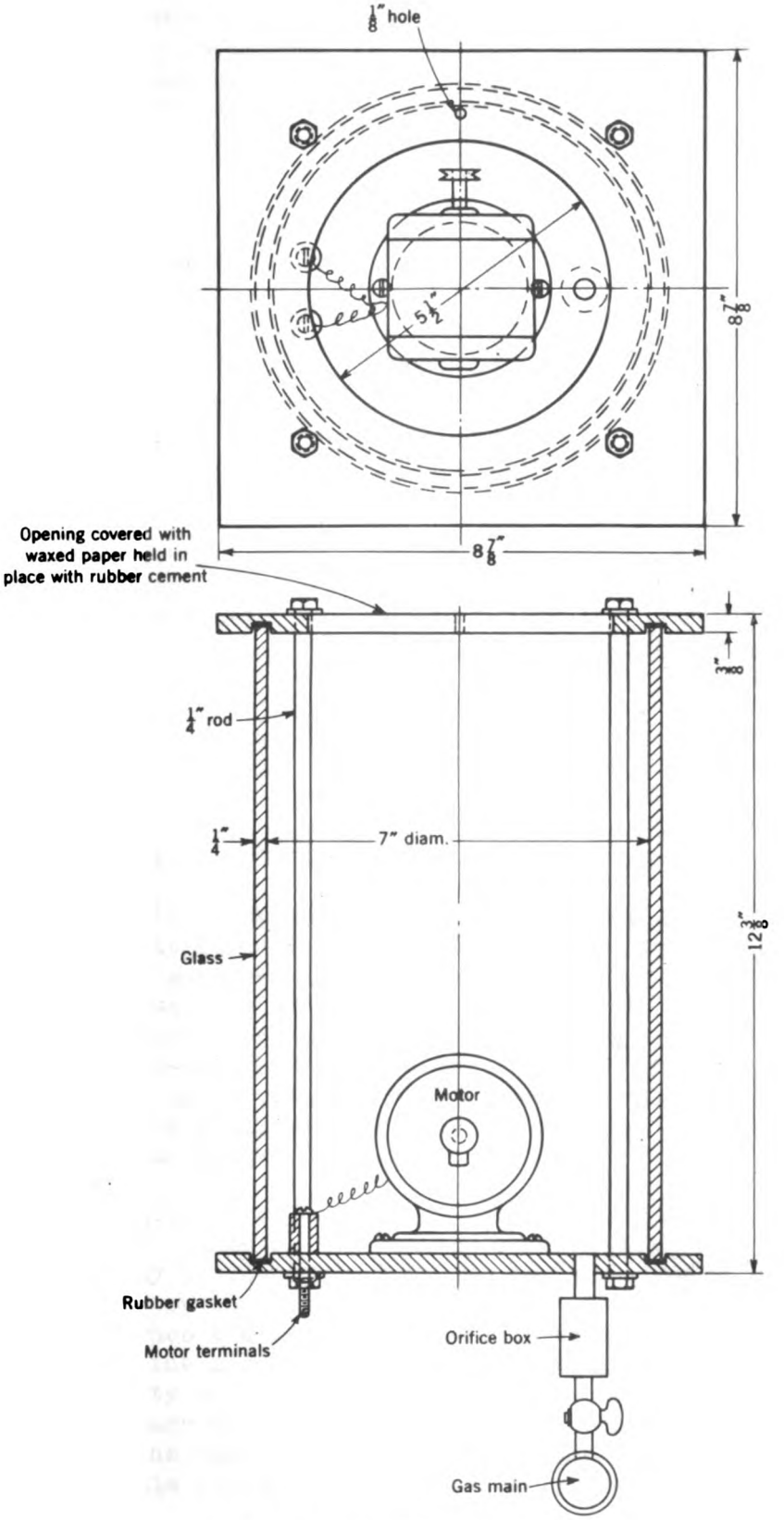

Figure 1.- Sectional view of demonstration chamber

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that connect the rail ends to form a continuous circuit may become loose through corrosion or may be severed by derailed cars. Thus, it is possible for sparking to take place between the rail and the end of the bond or between separated ends of the bond. The situation in which one end of a compressed terminal bond has loosened in the rail is represented in the third chamber. Ignition of the explosive atmosphere in this chamber follows when an arc is made by touching the end of the bond to the side of the hole. With 110 volts direct current applied, a current of 10 amperes is permitted to flow for this demonstration.

Power and trolley circuits can be eliminated by the use of storage-battery locomotives and power trucks approved by the Bureau of Mines. Approved locomotives are available for both gathering and main-line-haulage service. Approved power trucks are equipped with a special plug and receptacle by which it is possible to connect a permissible mining machine, pump, air compressor, or any other approved motor-driven machine for operation on battery power.

The fourth chamber contains two 100-watt lamps and a single-pole knife-blade switch. These lamps are connected in parallel for operation on the 110-volt direct-current circuit. This means that the switch when opened interrupts a current of about 2 amperes. The spark produced when the switch is opened is shown to be capable of igniting the explosive mixture in the chamber. The demonstration proves that it may be unsafe to use open-type switches in gassy mines, even though the amount of current broken is relatively small. Safe illumination may be obtained by using approved floodlights and electric cap lamps. If switches must be used in gassy atmospheres they should be enclosed in explosion-proof housings to avoid exposed sparking.

The hazard of gas ignition can be introduced by common types of bare-wire signal circuits in which a bell is rung when the bare wires are brought together or some metal object connects them. The sparks at the make-and-break contacts of the bell can be sufficiently intense to ignite gas. This fact is proved in the fifth chamber, which contains a bell connected to a 16-volt storage battery. The current taken is between 2 and 3 amperes. Bells with explosion-proof housings for the coils and sparking parts can be obtained in England. No explosion-proof bells have been produced in the United States.

Under certain conditions ordinary mine-type telephones may introduce an ignition hazard. For example, the ringing current generated by turning the generator handle may be interrupted by the moving contacts at the end of the generator shaft, or it may be interrupted at the hook-switch contacts, which separate when the receiver hook is pushed down. This interruption or breaking of the circuit results in sparking capable of igniting mine gas; the possibility of doing so is illustrated in the sixth chamber, which contains an ordinary desk-type telephone with the stand cut away to permit observation of the contacts that move when the receiver hook is raised and lowered. This telephone is electrically connected to a mine

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telephone, so that when the ringer of the latter is operated the ringing current can be broken in the chamber containing an explosive mixture. In this demonstration the voltage may reach as high as 130, but the current is so small that the spark cannot be seen easily.

One make of telephone approved by the Bureau of Mines is available for use in gassy and dusty mines. This telephone contains two explosion-proof housings, in which the hook-switch and generator contacts are enclosed.

In the seventh chamber is a cartridge-type fuse with knife-blade contacts. It is mounted so that it can be inserted and withdrawn from a 110-volt circuit in which a current of about 10 amperes is flowing. This represents the condition that exists when it is attempted to change a fuse in a live circuit. In such a case it is possible that sparks will be produced and ignite explosive atmospheres surrounding the fuse. An ignition is produced in this manner in the seventh chamber. When fuse protection is employed in certain equipment approved by the Bureau of Mines it is required that the fuses be enclosed in an explosion-proof housing provided with an interlocking mechanism that makes access to fuses impossible before the fuse contacts are "dead". Usually this means that the fuse compartment cannot be opened until a switch ahead of the fuses has been opened.

Many open-type motors are used in mines to operate pumps, compressors, and other machines. The construction of these motors permits the ready entrance of gas into their casings. In the case of direct-current motors, the sparks between the commutator and brushes can be intense enough to ignite explosive atmospheres. A 110-volt, fractional-horsepower, open-type motor when started in the eighth chamber causes an explosion of the mixture contained in it. Explosion-proof motors should be used on machines operated in gassy mines. Machines approved by the Bureau of Mines are required to have such motors. These motors are subjected to tests in explosive atmospheres, in which they must demonstrate that they can withstand internal explosions without bursting or discharging flames through any joint or bearing and without causing the surrounding explosive atmosphere to ignite.

The ninth chamber contains a miners' cap-lamp bulb mounted so that the glass can be broken away while the filament is lighted. The gas in the chamber is ignited when the heated filament is exposed. Although the current and voltage are comparatively low - that is, about 1 ampere at 4 volts - the temperature of the filament is high enough to raise the gas to ignition temperature. This shows why the Bureau of Mines requires that miners' approved lamps be fitted with a special bulb mounting that will cause the bulb to be ejected when it is broken. Thus, the bulb is deprived of current and the filament cools so quickly that no ignition of gas occurs.

Another gas-ignition hazard may arise when explosives are fired electrically to dislodge the coal. The wires leading to the electric blasting cap or detonator may touch and separate with voltage still applied and so produce sparks. If the voltage and current are high enough,

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and an explosive atmosphere is present, ignition will occur. The tenth chamber contains a horizontal, circular disk with a row of closely spaced vertical pins set near the circumference of the disk. When the latter is rotated, the ends of the pins touch a stationary metal strip. This arrangement simulates the ends of wires making and breaking contact. Electrical connections are made to the outside of the chamber so that sparks can be made to jump between the ends of the pins and the stationary metal strip. The first sparks are produced by operating a single-shot blasting unit approved by the Bureau. Although the sparks are numerous they are of low intensity, and no ignition of the gas in the chamber takes place. However, when a blasting unit of 5-shot capacity is operated in the same manner, ignition of the gas takes place immediately. The explanation for this is that the unit of greater capacity must deliver a larger current at a higher voltage to fire the larger number of shots successfully. In other words, designing the permissible unit with electrical characteristics such that the sparks it produced were too feeble to cause an ignition meant that its capacity was limited to one shot. It is to be noted that the permissible unit carries an "approval plate". This identification signifies that the unit has successfully passed certain tests made by the Bureau of Mines to determine whether it could be operated with safety in gassy mines.

Every device and machine approved by the United States Bureau of Mines must have an approval plate attached to it, by which it can be distinguished from those that may not have been constructed with safety in view. If none but correctly maintained permissible equipment were used in a mine, and if all other proper precautions, such as adequate ventilation and rock dusting, were observed, the possibility of mine explosions would be reduced to a minimum and the stigma of being a most hazardous occupation would no longer attach to the mining of coal.

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